Cosmic Ray Backgrounds

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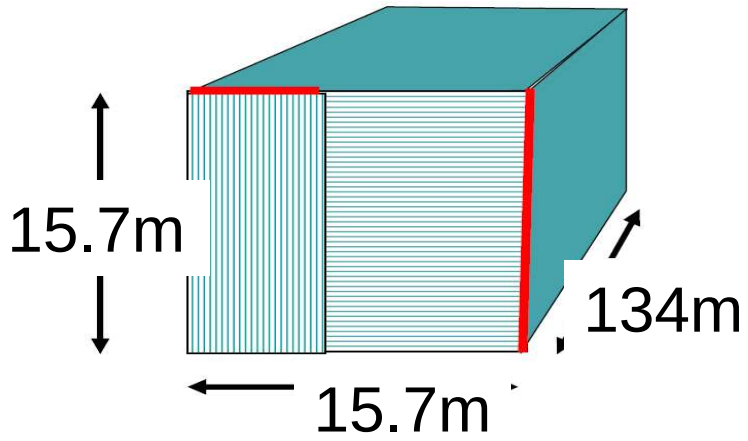
Ground Level Components

- **Muons**
  - Vertical Diff flux @1GeV ~30/m²/s/sr/GeV
    - Vert Integral Flux > 1GeV = 80/m²/s/sr*2000m²sr=0.2MHz
  - Angular distribution ~cos²(θ)
  - ~E^{-1},E^{-2},E^{-3} (1,10,100 GeV/c)
- **Neutrons**
  - Vertical Diff flux @1GeV ~1/m²/s/sr/GeV
    - Vert Integral Flux > 1GeV = 0.4/m²/s/sr*2000m²sr=0.8kHz
  - Angular distribution ~exp(-8(secθ-1))
  - ~$E^{-2.7}$
- **Photons**
  - Vertical Diff flux @1GeV ~1/m²/s/sr/GeV
    - Vert Integral Flux > 1GeV = 0.4/m²/s/sr*2000m²sr=0.8kHz
  - Angular distribution ~exp(-8(secθ-1)) -> exp(-1.1(secθ-1))
  - ~$E^{-2.7}$

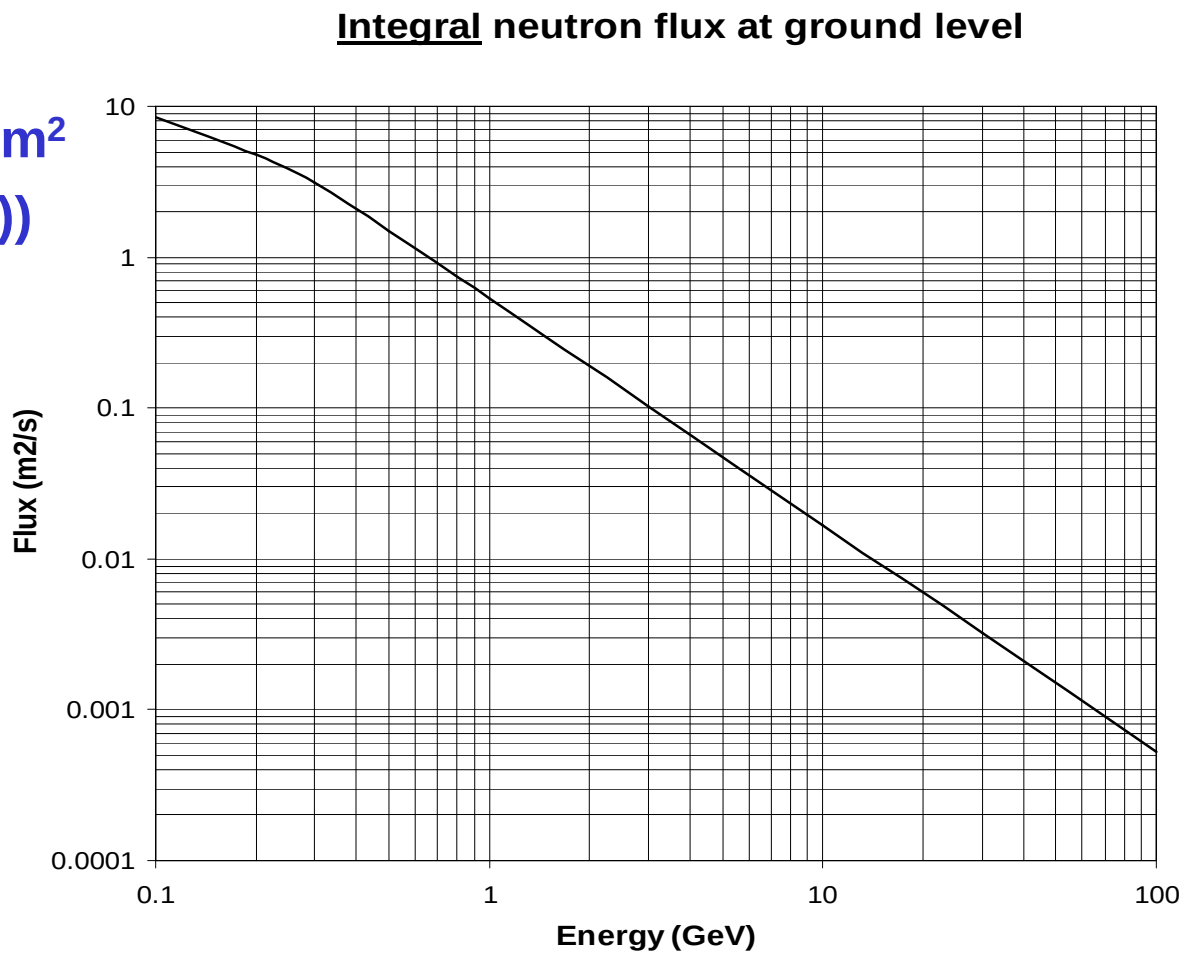
Simulations of Cosmic Ray Induced Backgrounds

- Ground-level neutrons and photons
- Detector: 15.7x15.7x134m ~2000 m^2 effective area)
- Generate neutron and photon fluxes with
  - **zenith angle random in cosθ, bins of 0.1**
  - **random energy (flat 1-4GeV)**
  - **random azimuthal angle**
  - **random position on detector**
- Analyze with PJL standard selections



Neutrons

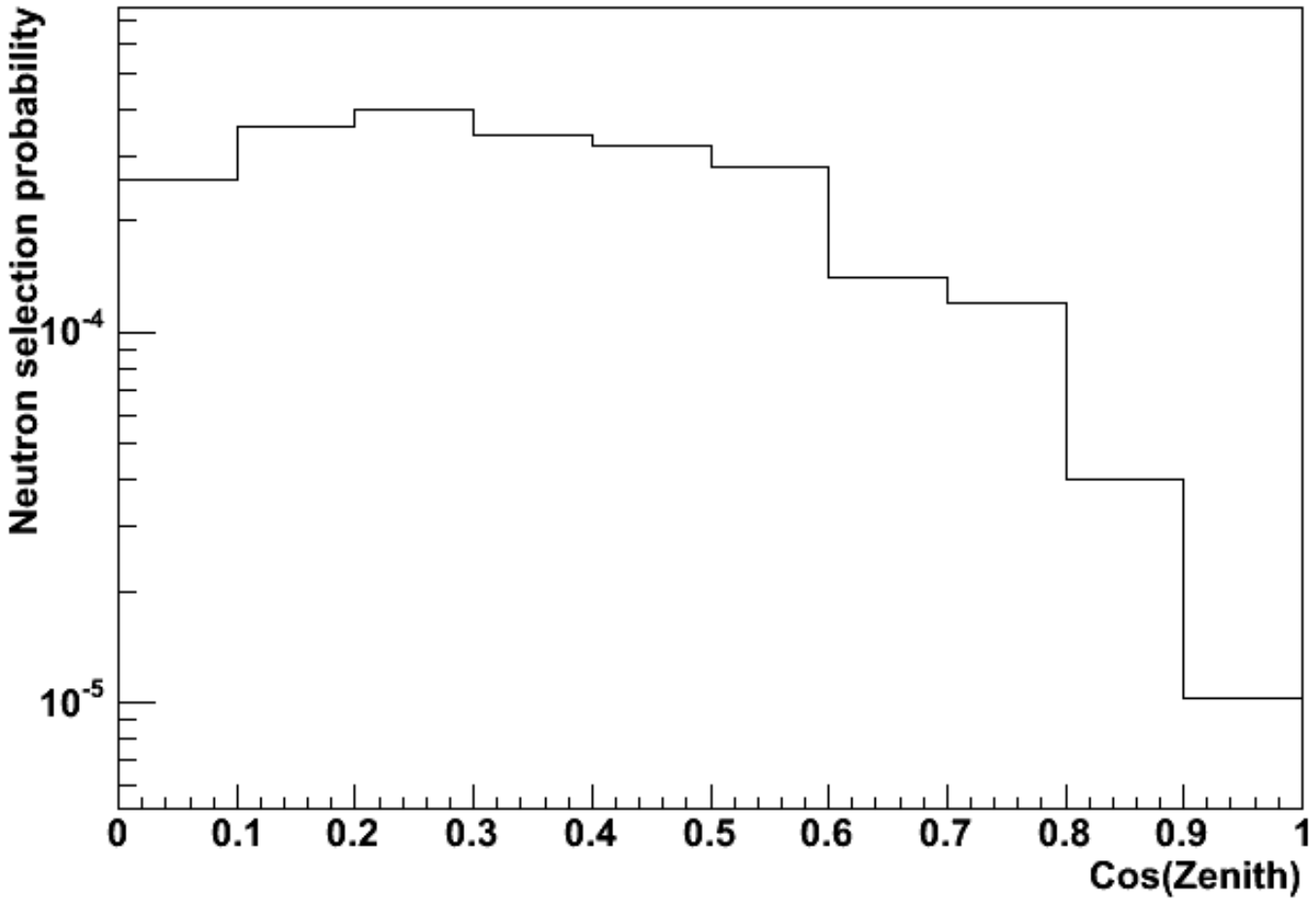
- Data from Ashton, "*CR at ground level*", ed. Wolfendale (1974)
- Atten. Length: ~120 g/cm^2
- I(θ) = I(0)exp(-8(sec θ -1))



Neutron Selection Probability

(Using Standard Analysis)

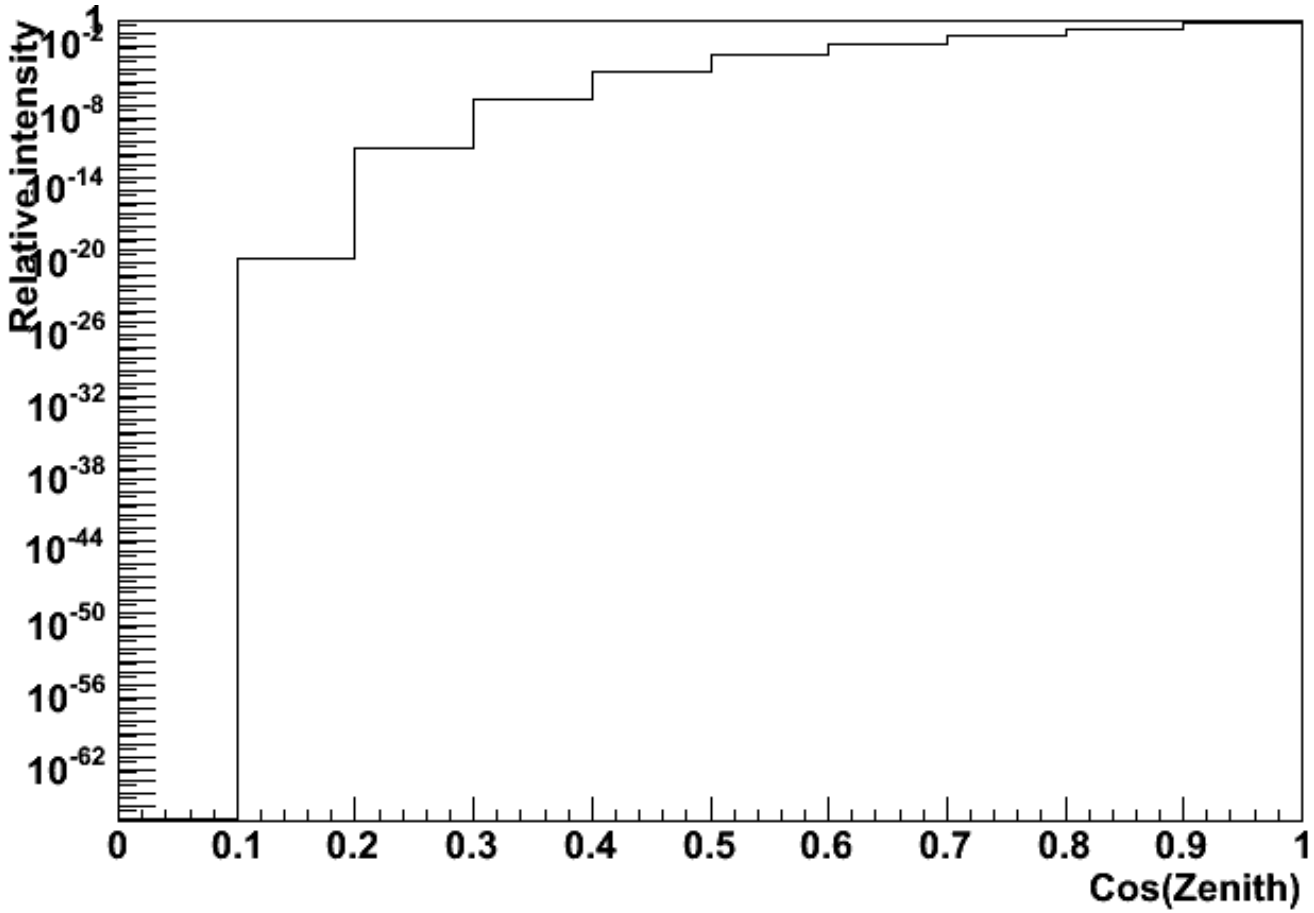
Probability of selecting a neutron as a function of zenith angle: P(θ)



Neutron Rate vs. Angle

Integral neutron rate (neutrons/s) as a function of angle:

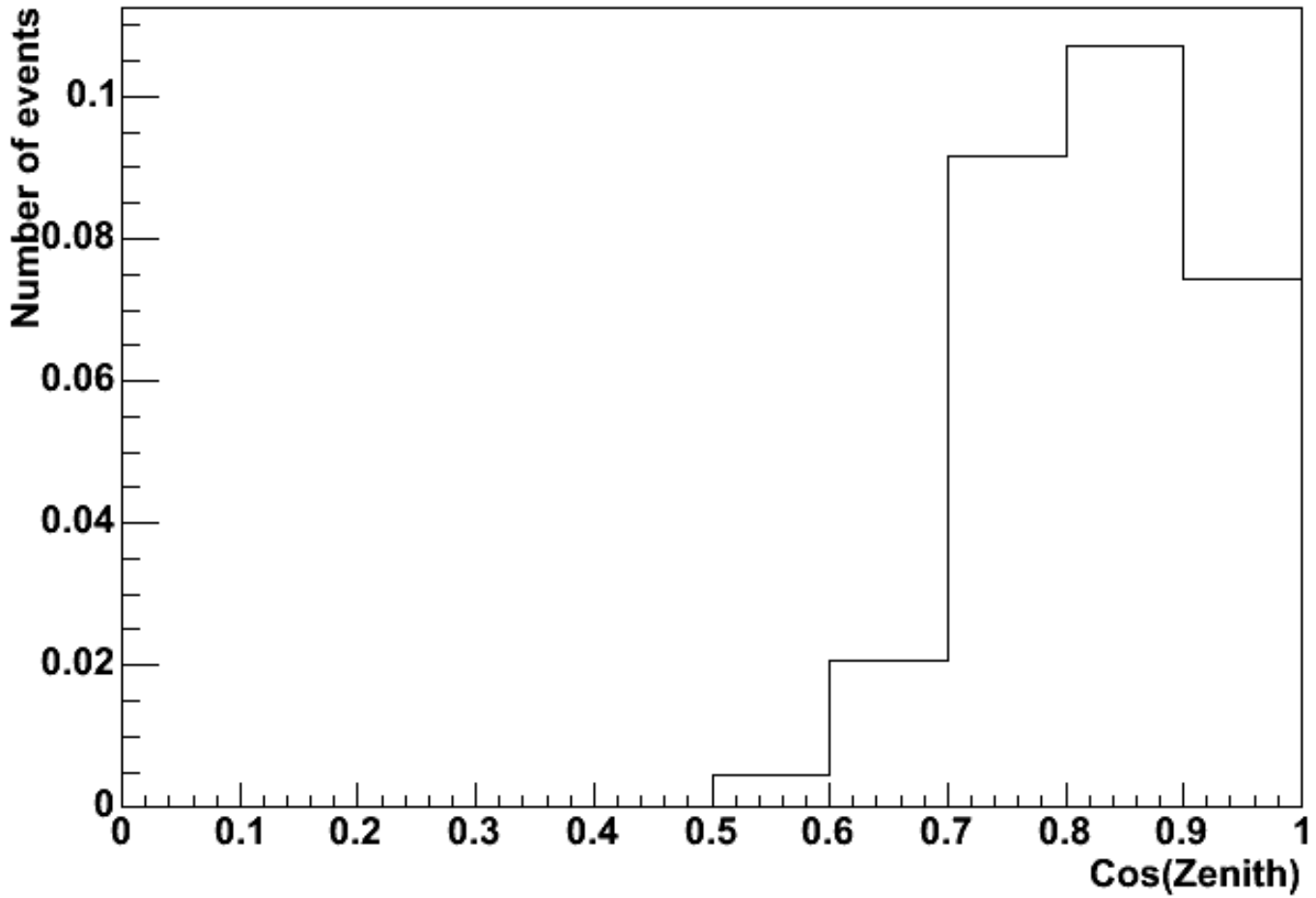
$R(\theta) = I(0) * \exp(-8(\sec\theta - 1)) * \text{acceptance}(\theta) * d\cos\theta$



Selected Neutron Event Distribution

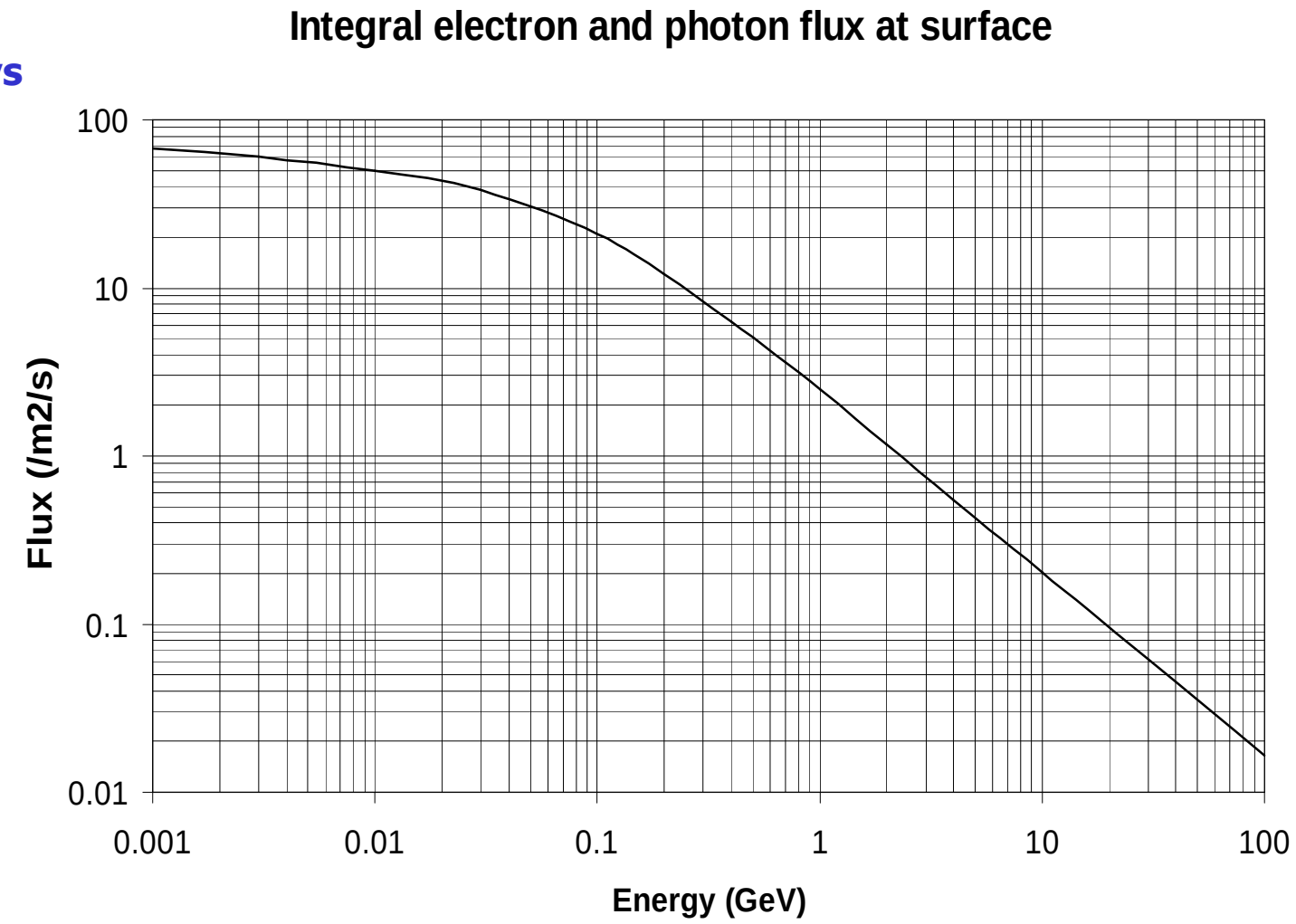
$N(\theta) = P(\theta) * R(\theta) * T$

Total Events =0.30 in 5 year exposure (500s live)



Electrons and photons

- Data from Daniels and Stephens; Revs Geophys. And Space Sci. 12, 233(1974)
- ~$\cos^2\theta$ for $\theta < 60^o$
- Median energy ” 10s of MeV
- Attenuated as ~exp(-x/175g.cm^{-2})



Photon Background

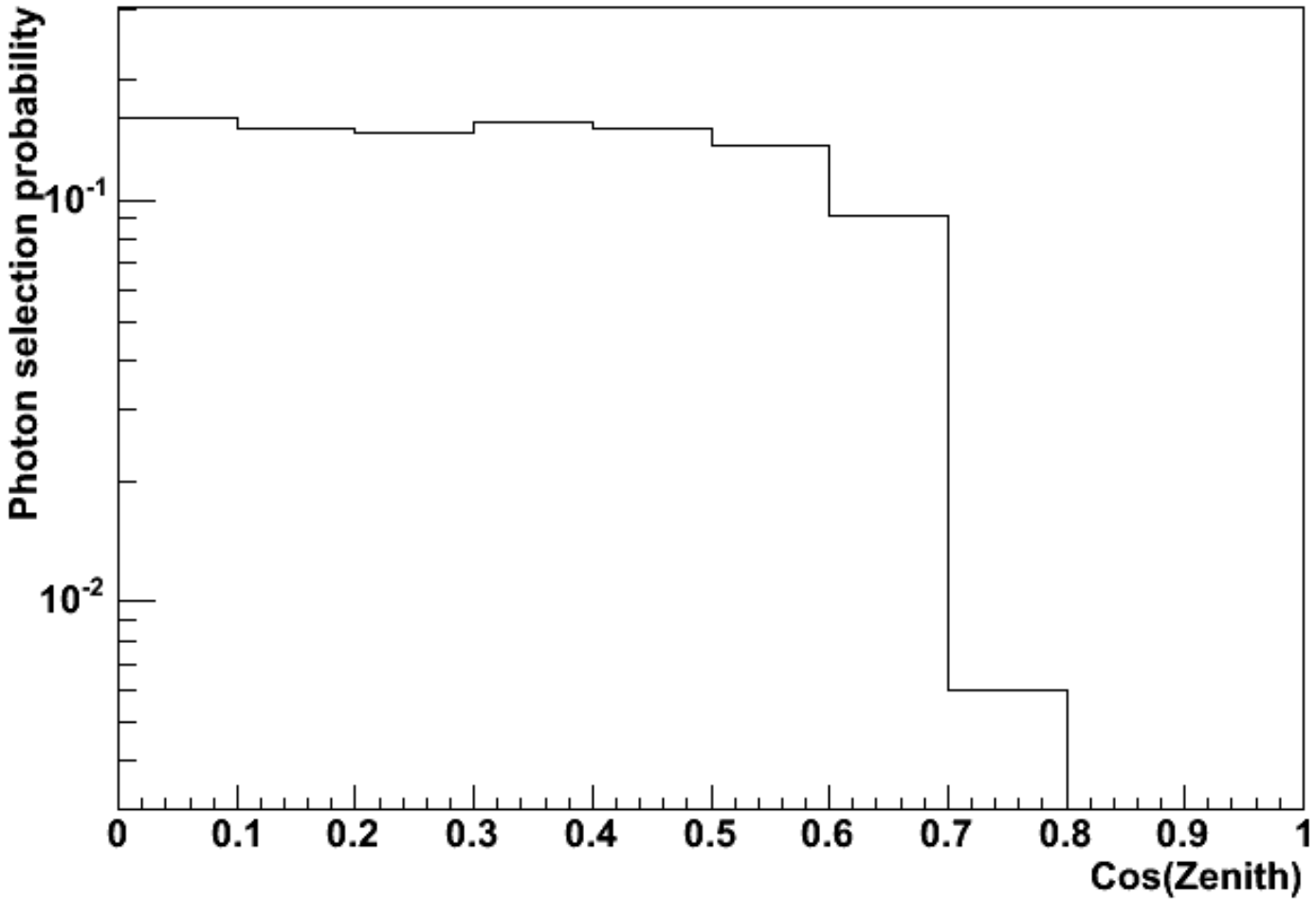
Considered likely to be selected as electron event –EM interactions

- **Angular suppression not as strong as neutrons**
- **Difficult to simulate correctly (easily)**
  - Photons are from hadronic interactions production of π^0; Associated particles should aid rejection
    - Need to start with parent particles –N or P
  - Photons can be seen from relatively far away
    - Need to simulate large volume (X_0=300m!)
- **Estimate upper limit by simply simulating the photons as was done for neutrons**

Photon Selection Probability

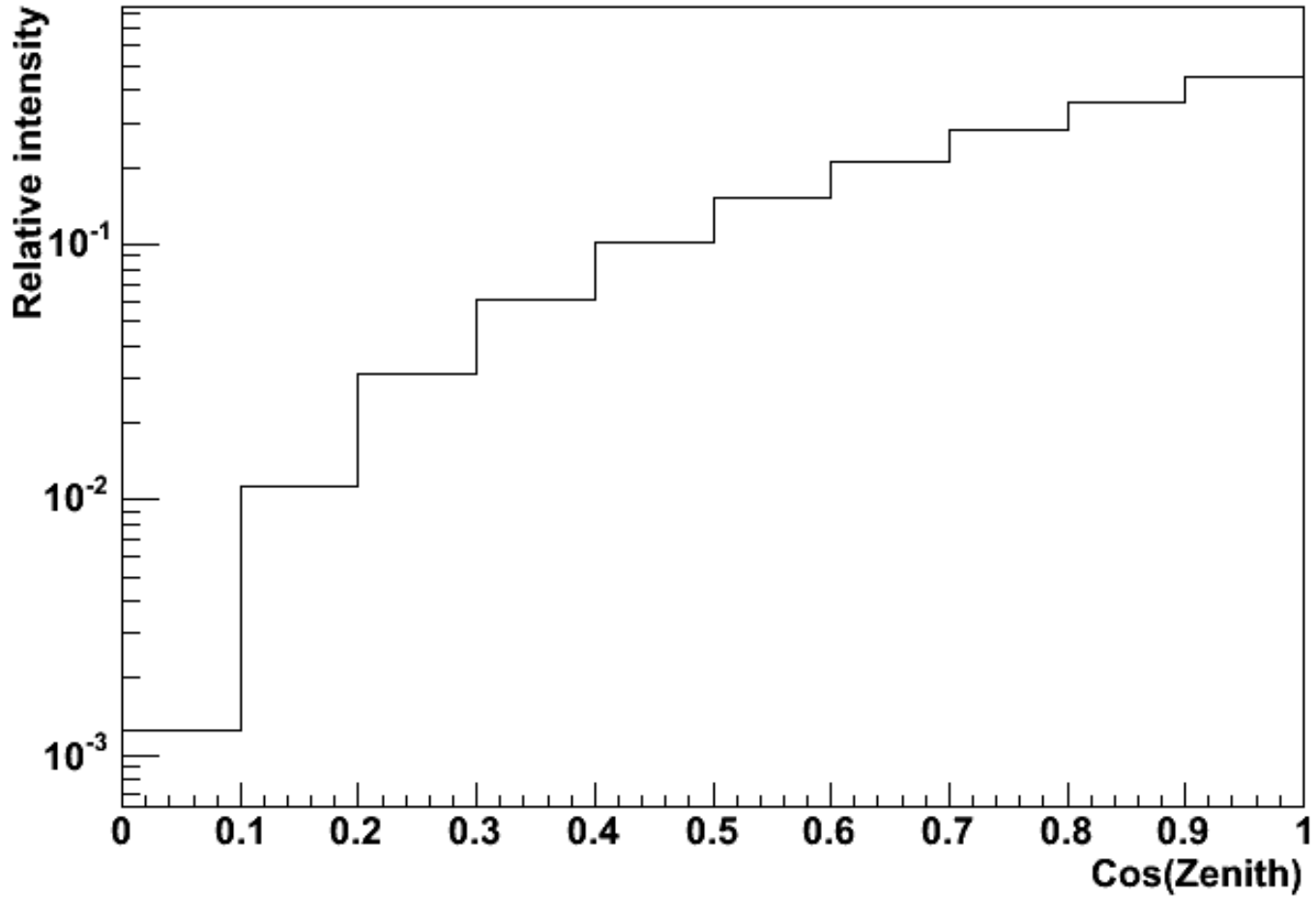
(Using Standard Analysis)

Probability of selecting a photon as a function of zenith angle: P(θ)



Photon Rate vs. Angle

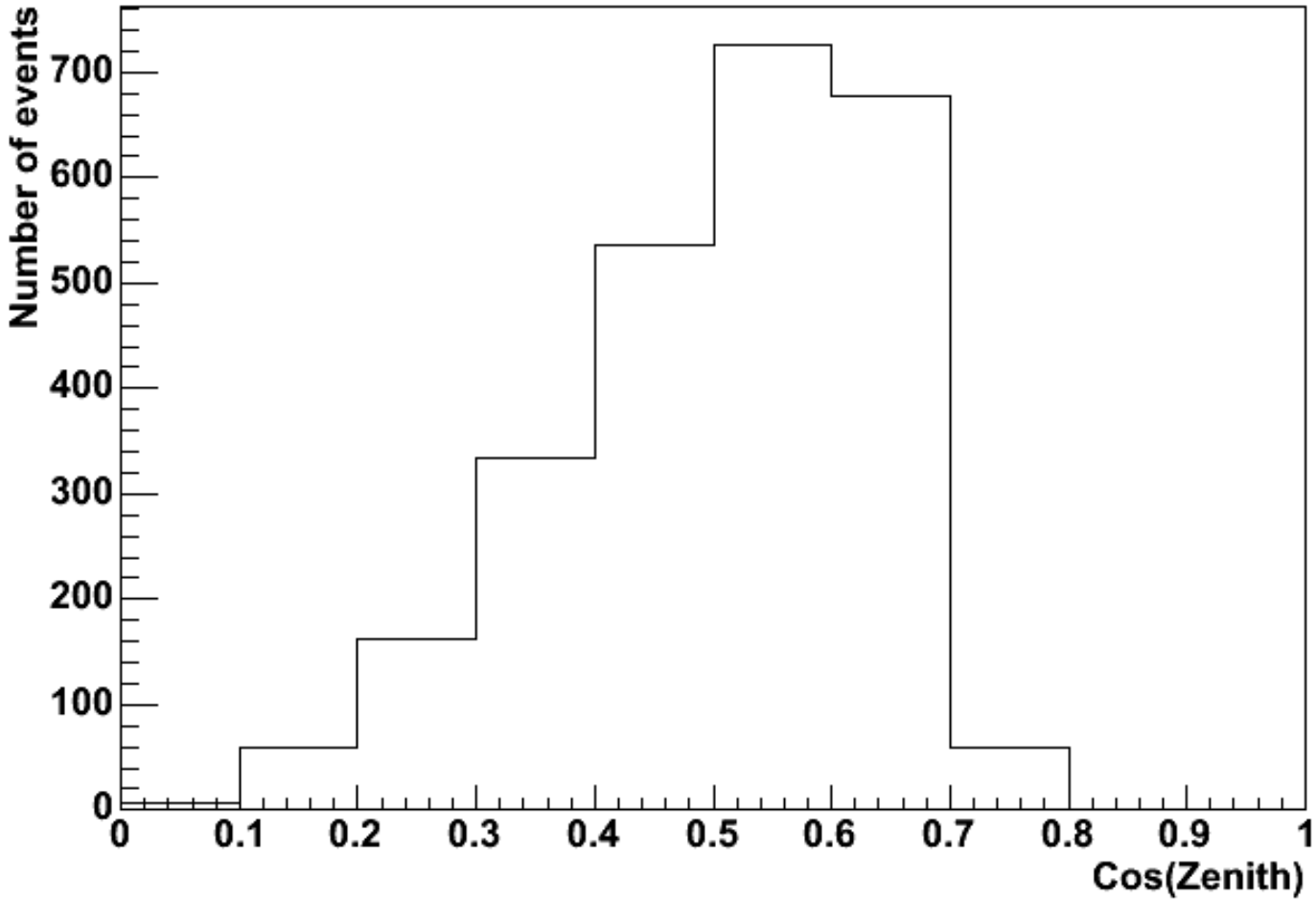
Integral photon rate (photons/s) as a function of angle:
$R(\theta)=I(\theta)*$ acceptance(θ) $*d\cos\theta$



Selected Photon Event Distribution

$N(\theta) = P(\theta) * R(\theta) * T$

Total Events =2600 in 5 year exposure (500s live)

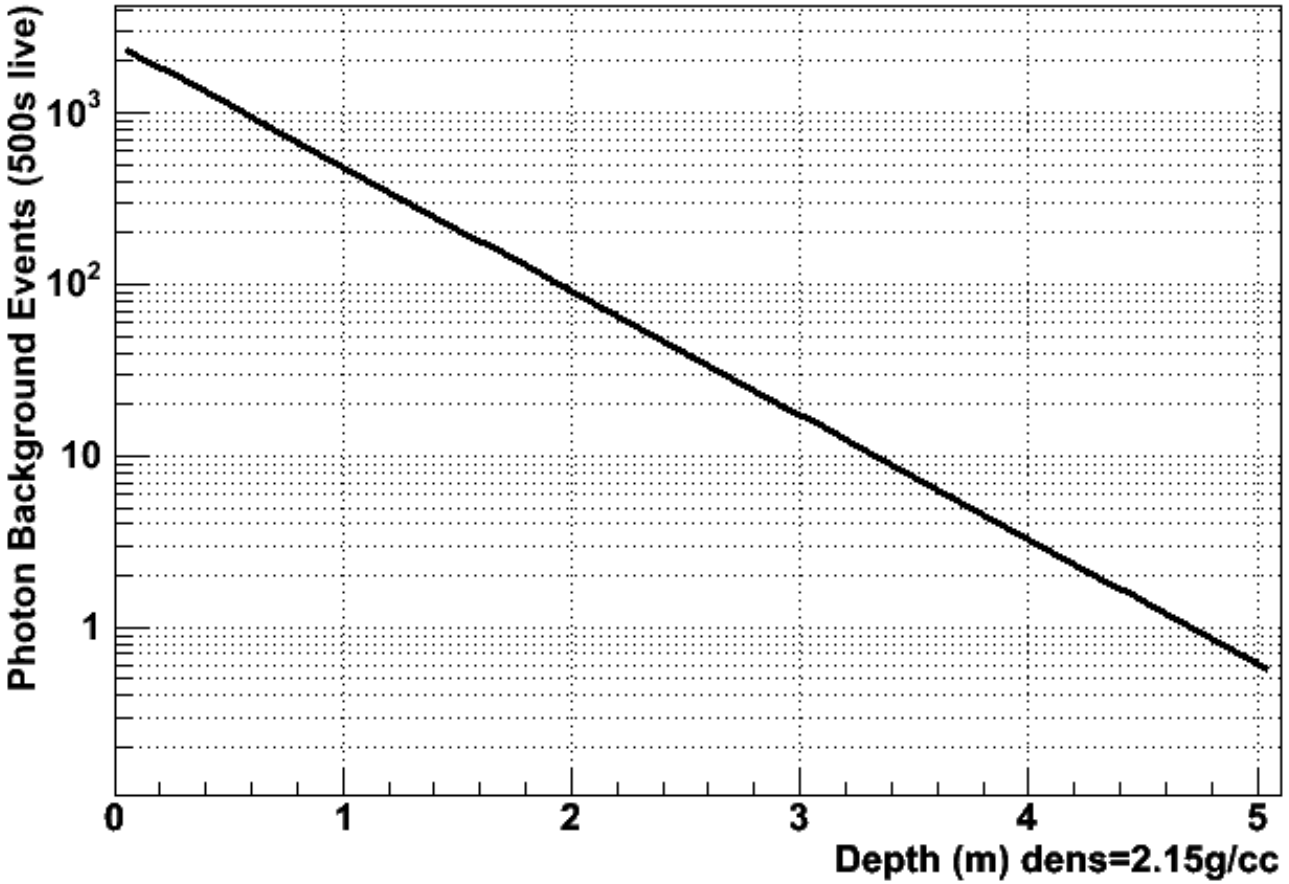


Photon reduction possibilities

- **Where can we go from here?**
  - 2600 events is an unacceptable level of background
- **Additional reduction**
  - Containment/Fiducial cuts
    - Interaction length ~80cm, current cut 15cm
    - increase, and increase on front/back faces
  - Angular cuts
    - currently at 45 degrees for no impact on FOM
  - Correlated events
    - How much flux comes in clusters, CORSIKA simulation
  - Overburden
    - Attenuation length ~125g/cm² ; ~ 60cm

Photon background vs. Overburden depth

- Reduction from 2560 events of photon background vs. depth

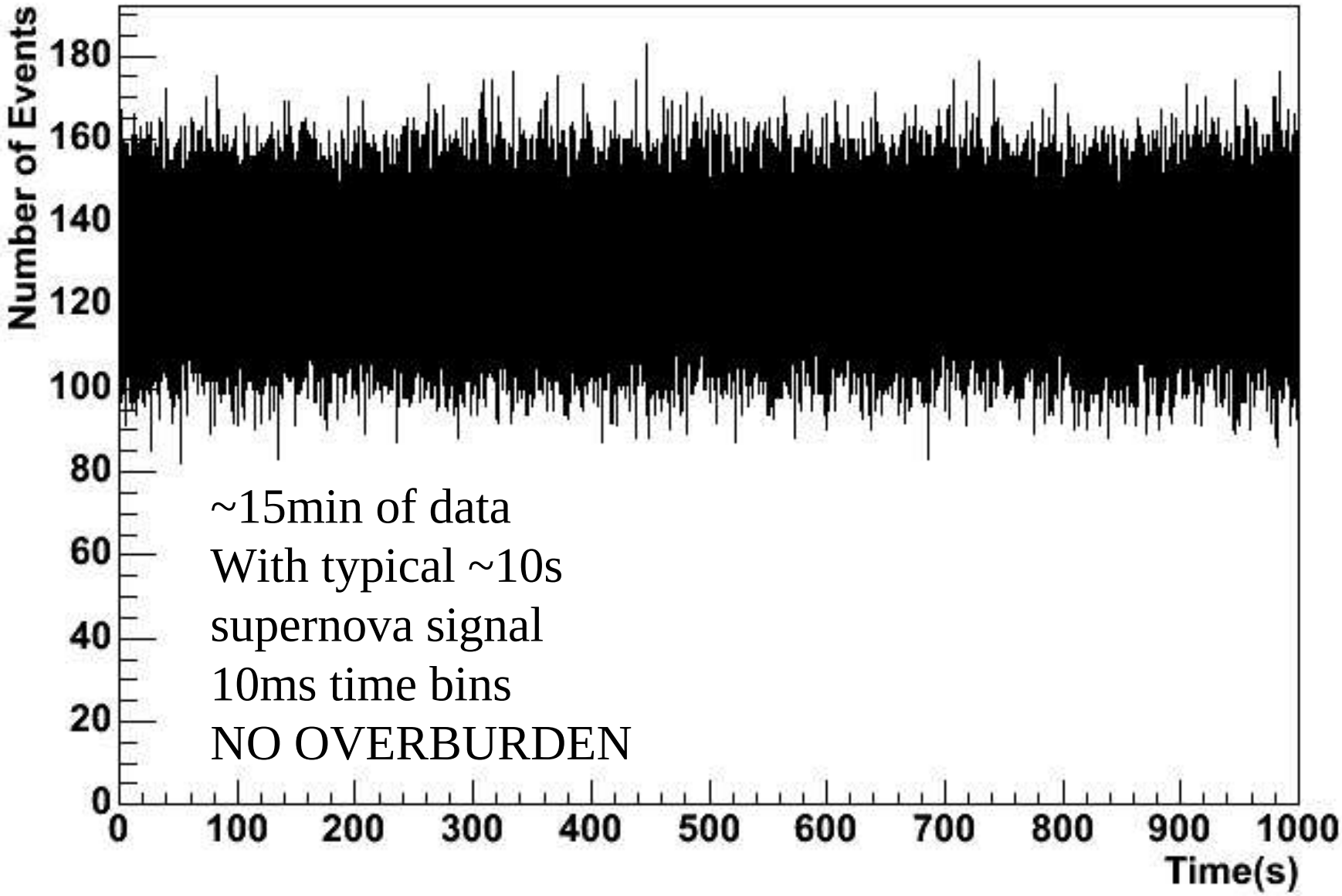


Potential side effects

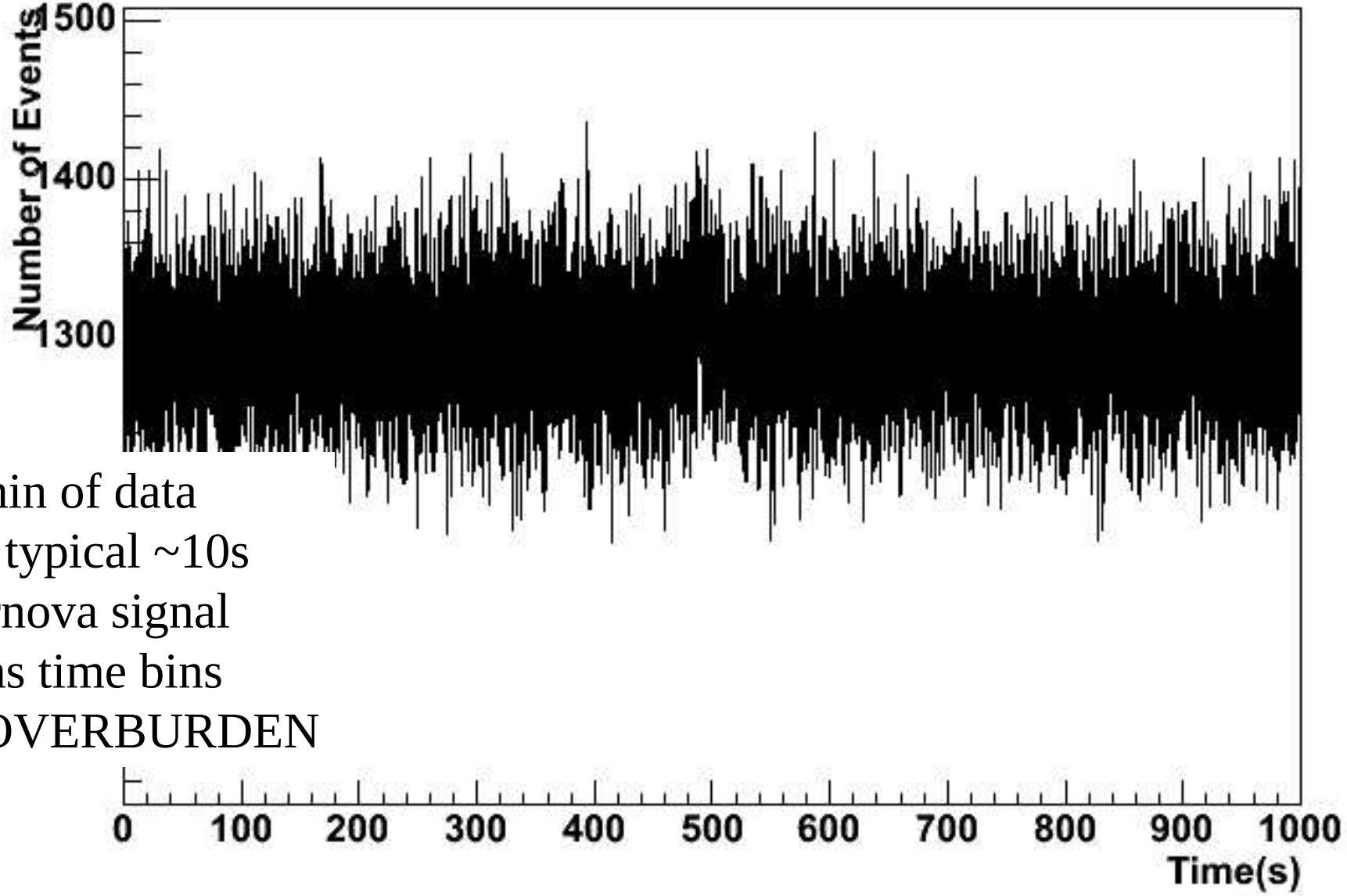
- **Better climate control**
  - (handy in Northern Minnesota)
- **Vastly improved SuperNOvA detection**

Depth	Signal	EM bkd	Neutron	S/sqrt(b)
0m	1500	10,000	3,000	13
1m	1500	1800	424	30
2m	1500	320	60	77
3m	1500	57	8.5	185
4m	1500	10	1.2	450

Find the SuperNOvA

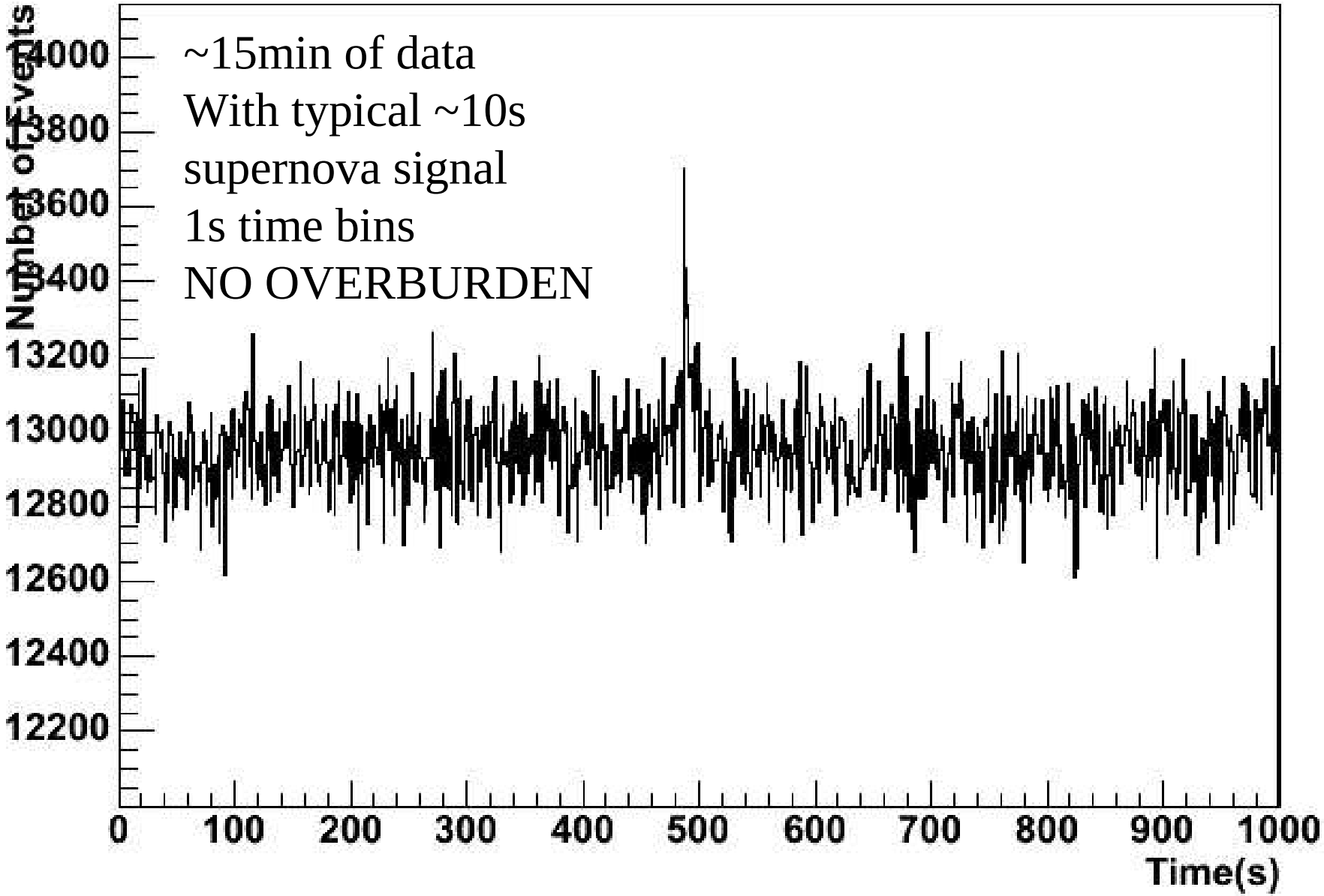


Find the SuperNOvA



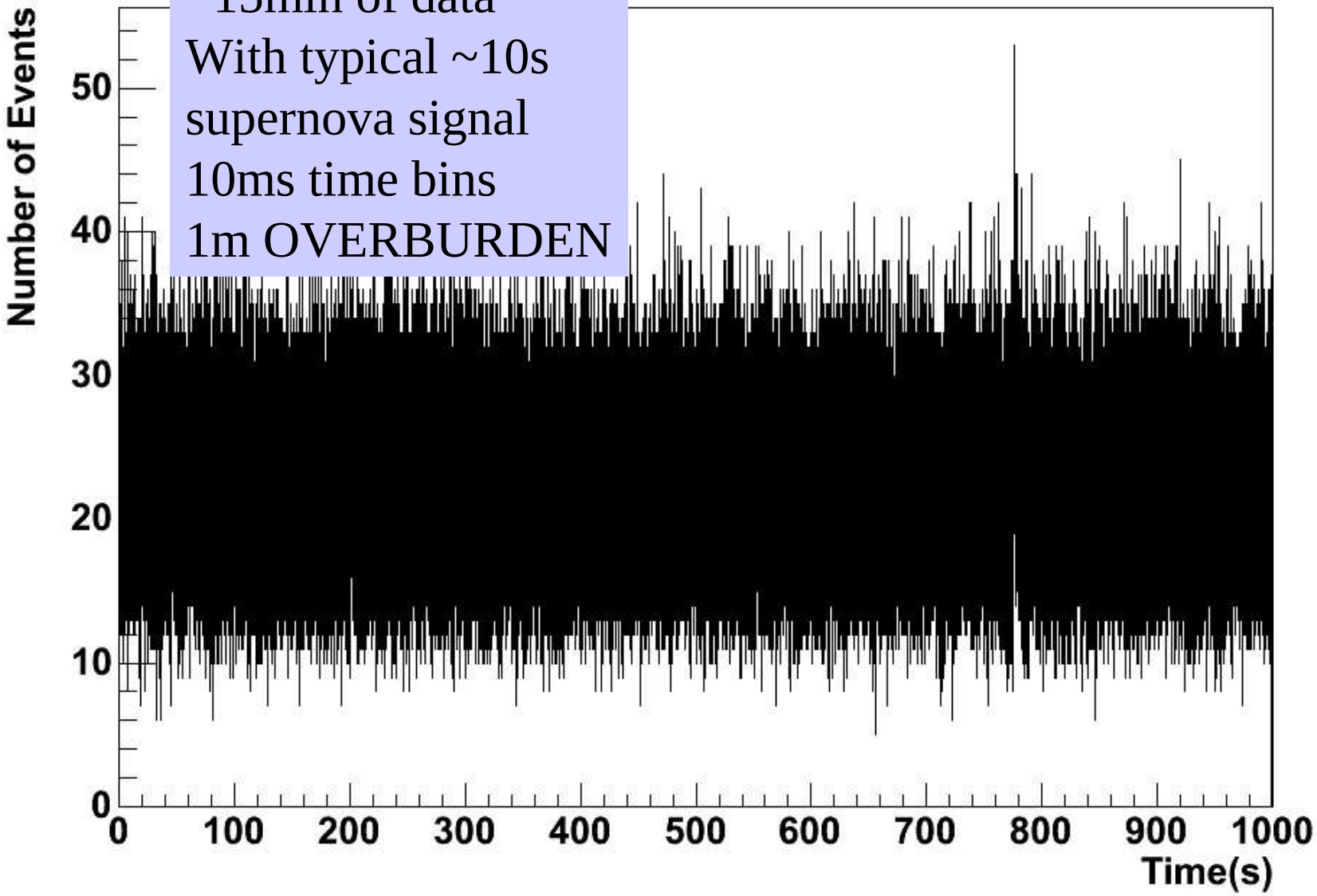
~15min of data
With typical ~10s
supernova signal
100ms time bins
NO OVERBURDEN

Find the SuperNOvA

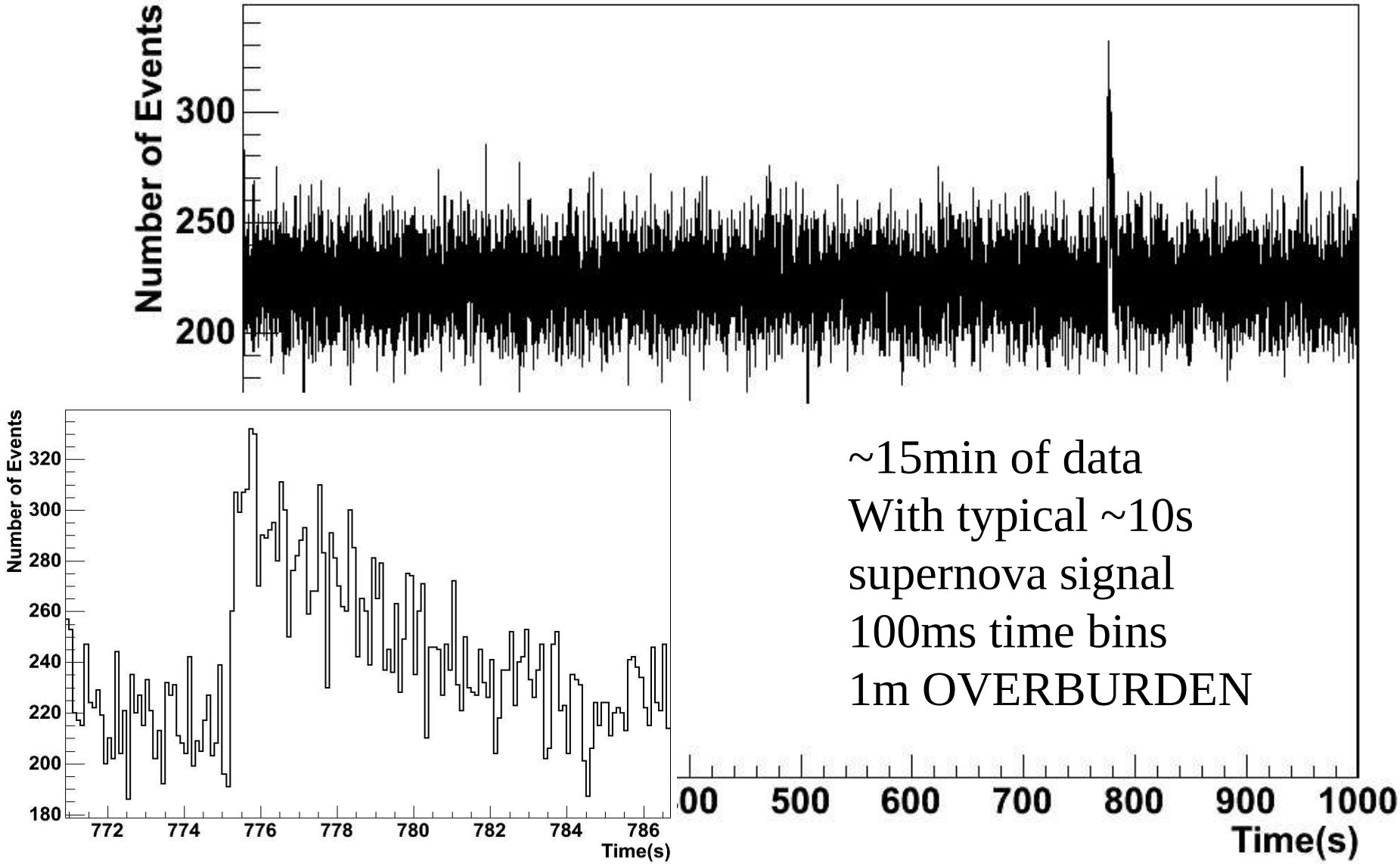


Find the SuperNOvA

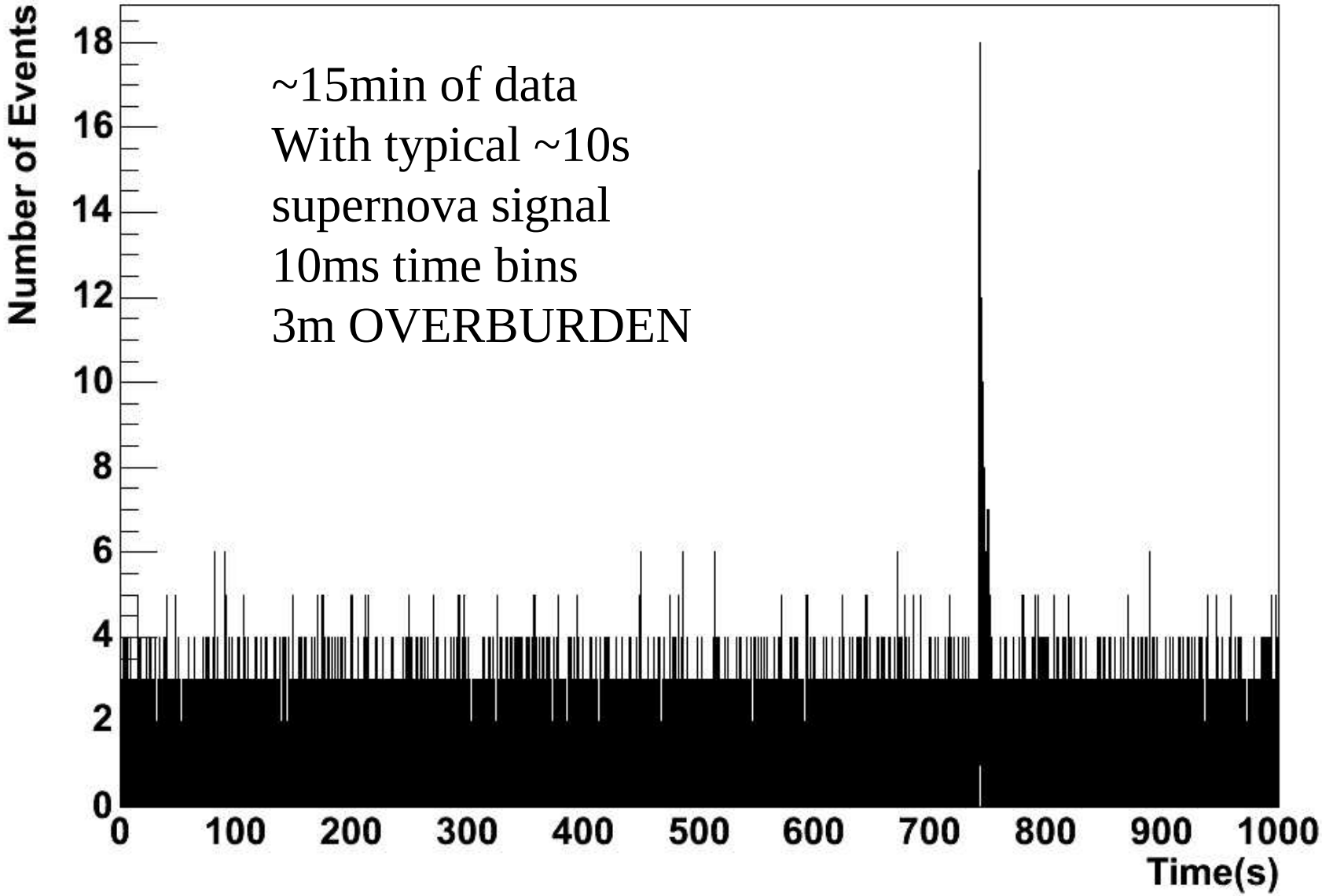
~15min of data
With typical ~10s supernova signal
10ms time bins
1m OVERBURDEN



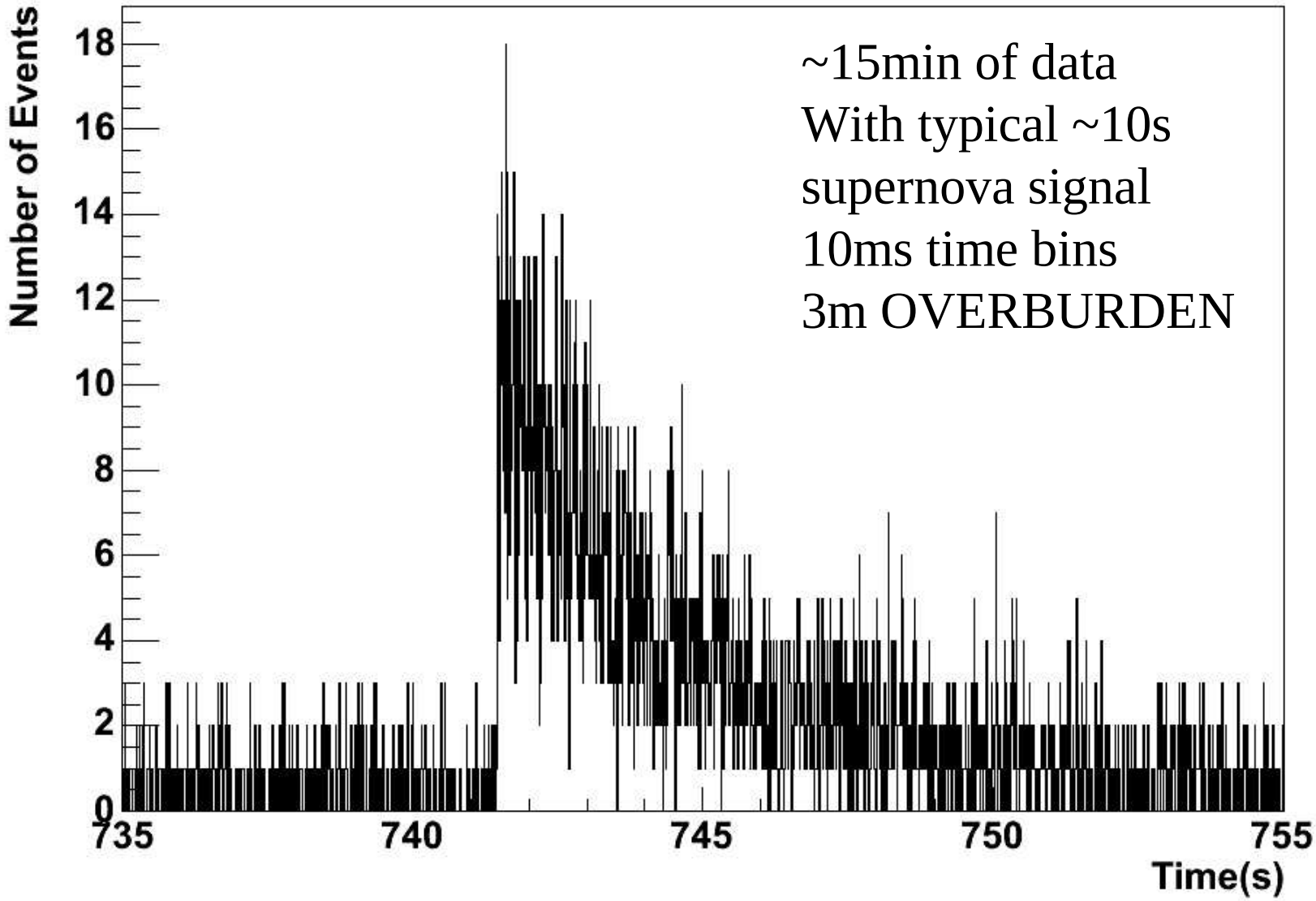
Find the SuperNOvA



Find the SuperNOvA



Find the SuperNOvA



Conclusions

- **EM background appears substantial**
  - Possible help
    - Increase cuts, length, angle, correlations
    - Reduces signals
    - Probably not enough
  - Ostrich Solution
    - Doesn’t affect signals
    - Substantial increase in Supernova sensitivity
    - ….